CLAIMS

1. A method of controlling a surgical instrument that is inserted in a patient for facilitating a surgical procedure and controlled remotely from an input device manipulated by a surgeon at a user interface, said method comprising the steps of:

initializing the position of the surgical instrument without calculating its original position, and the position of the input device under electronic control;

said initializing including establishing an initial reference position for the input device and an initial reference position for the surgical instrument

calculating the current absolute position of the input device as it is manipulated by the surgeon;

determining the desired position of the surgical instrument based upon;

the current position of the input device,

the reference position of the input device, and

the reference position of the surgical instrument, and

moving the surgical instrument to the desired position so that the position of the surgical instrument corresponds to that of the input device.

2. A method as set forth in claim 1 wherein the input device has position sensors, and the step of initializing includes initializing these position sensors.

3. A method as set forth in claim 2 wherein the initializing is to zero.

4. A method as set forth in claim 1 including computing an initial reference orientation for the input device.

5. A method as set forth in claim 4 including computing a desired orientation for the surgical instrument.

6. A method as set forth in claim 5 including computing a desired position for the surgical instrument.

7. A method as set forth in claim 1 wherein said initializing step includes performing a forward kinematic computation from the input device.

8. A method as set forth in claim 2 including reading position sensor values and current time.

9. A method as set forth in claim 8 wherein the calculating step includes calculating both the position and orientation of the input device.

10. A method as set forth in claim 1 including calculating the current orientation of the input device.

11. A method as set forth in claim 1 wherein said step of determining includes performing an inverse kinematic computation.

12. A method as set forth in claim 1 wherein said determining step includes a transformation into an earth coordinate system.

13. A method as set forth in claim 12 wherein from said transformation there are determined joint angles and drive motor angles for the surgical instrument orientation.

14. A method of controlling a tool of a surgical instrument that is inserted in a patient for carrying out a surgical procedure and is controlled remotely by way of a controller from an input device at a user interface, said method comprising the steps of:

setting the input device at an initial reference configuration and under controller control;

setting the surgical instrument in the patient at an initial predefined reference configuration without controller control;

calculating the current absolute position of the input device;

determining the desired location of the tool by a kinematic computation that accounts for at least the initial reference configuration of the input device and the current absolute position of the input device; and

moving the surgical instrument to the desired position so that the location of the tool corresponds to that of the input device.

15. A method as set forth in claim 14 wherein said step of determining is also based upon the initial reference configuration of the tool.

16. A method as set forth in claim 14 wherein the input device has position sensors, and the step of setting includes initializing these position sensors.

17. A method as set forth in claim 14 including computing an initial reference orientation for the input device.

18. A method as set forth in claim 14 including computing a desired orientation for the surgical instrument.

19. A method as set forth in claim 14 wherein said calculating step includes performing a forward kinematic computation from the input device.

20. A method as set forth in claim 14 including calculating the current orientation of the input device.

21. A method as set forth in claim 14 wherein said step of determining includes performing an inverse kinematic computation.

22. A method as set forth in claim 14 wherein said determining step includes a transformation into an earth coordinate system.

23. A method as set forth in claim 22 wherein from said transformation there are determined joint angles and drive motor angles for the surgical instrument orientation.

24. A system for controlling an instrument that is inserted in a patient to enable a surgical procedure and controlled remotely from an input device controlled by a surgeon at a user interface, said system comprising:

a base;

a first link rotatably connected to said base;

an elbow joint for rotatably connecting the second link to the first link;

a handle;

a wrist member connecting the handle to the distal end of the second link; and

a controller coupled to at least said base and links and for receiving signals representative of;

a rotational position of the base,

a rotational position of the first link relative to the base, and

a rotational position of the second link relative to the first link.

25. A system as set forth in claim 24wherein said controller also receives signals representative of the angle of the wrist member relative to the second link and the rotary angle of the wrist member relative to the second link.

26. A system as set forth in claim 25 wherein said controller also receives signals representative of the angles associated with fingers of the tool.

27. A system as set forth in claim 24 wherein said wrist member comprises a wrist joint.

28. A system as set forth in claim 24 including at least one position sensor associated respectively with the base, first link and second link.

29. A system as set forth in claim 28 wherein signals from the position sensors couple to the controller.

30. A system as set forth in claim 29 wherein an initial reference position of the base and links is established prior to manipulation by the surgeon.

31. A control system for an instrument that is controlled remotely from an input device, said system comprising:

a forward kinematics block for computing the position of the input device;

an initialization block for storing an initial reference position of said input device;

an inverse kinematics block coupled from said forward kinematics block and said initialization block for receiving information from said forward kinetics block of the current input device position; and

a controller block coupled from said inverse kinematics block for controlling the position of the instrument in response to manipulations at the input device.

32. A control system as set forth in claim 31 including a scaling block coupled between said forward kinematics block and said inverse kinematics block for scaling motions imparted at the input device.

33. A control system as set forth in claim 32 including an output from said forward kinematics block directly to said inverse kinematics block representative of current input device orientation.

34. A control system as set forth in claim 33 including a combining device coupled from said forward kinematics block and said initialization block to said scaling block for providing a signal to said inverse kinematics block representative of desired instrument position.

35. A control system as set forth in claim 31 wherein said input device includes a wrist and a handle.

36. A control system as set forth in claim 35 wherein the position of the wrist is expressed in x, y and z coordinates.

37. A control system as set forth in claim 36 wherein the orientation of the handle is determined by a series of coordinate transformations.

38. A control system as set forth in claim 37 wherein a transformation matrix is provided for the handle coordinate frame with respect to a reference coordinate frame.

39. A control system as set forth in claim 37 including a transformation matrix R_{wh} for the wrist joint coordinate with respect to a reference coordinate, and a transformation matrix R_{hwh} for the handle coordinate with respect to the wrist coordinate.

40. A control system as set forth in claim 39 wherein a transformation matrix R_h for the handle coordinate with respect to the reference coordinate is:

$$R_h = R_{wh} R_{hwh}$$

41. A method of controlling a medical implement remotely from an input device that is controlled by an operator, said method comprising the steps of:

positioning the medical implement at an initial start position at an operative site for the purpose of facilitating a medical procedure;

establishing a fixed position reference coordinate representative of the initial start position of said medical implement based upon a base point of the implement and an active point of the implement being in a known relative dimensional configuration,

positioning the input device at an initial start position;

establishing a fixed position reference coordinate representative of the initial start position of said input device;

calculating the current position of the input device as it is controlled;

determining the desired position of the medical implement based upon;

the current position of the input device,

the fixed position reference coordinate of the input device, and

the fixed position reference coordinate of the medical implement, and

moving the medical implement to the desired position so that the position of the medical implement corresponds to that of the input device.

42. A method as set forth in claim 41 wherein, in said step of positioning the medical implement, the medical implement comprises a surgical instrument.

43. A method as set forth in claim 42 wherein, in said step of positioning the medical implement, the medical implement comprises a catheter.

44. A method as set forth in claim 41 wherein said step of positioning the medical implement includes physically placing the distal end of the medical implement at the operative site.

45. A method as set forth in claim 44 wherein said medical implement is placed without pre-computation of a coordinate position at which it is placed.

46. A method as set forth in claim 45 wherein said step of positioning the medical implement is only controlled by manual placement without any electric pre-computation of a predetermined coordinate position to control the actual placement of the medical implement

47. A method as set forth in claim 41 wherein, in said step of positioning the medical implement, the medical implement comprises a surgical instrument having a tool and a wrist,

said established reference coordinate corresponding to an initial position of a location on said wrist.

48. A method as set forth in claim 41 further including providing an electronic controller for controlling said medical implement and wherein the step of positioning the medical implement includes manually placing the medical implement without computation by said controller of an initial coordinate position.

49. A method as set forth in claim 41 further including providing an electronic controller for controlling said medical implement and wherein the step of positioning the input device includes initially moving the input device under controller control so as to establish the reference coordinate position of the input device.

50. A method as set forth in claim 42 including storing in the controller the reference coordinate position of the input device.

51. A method as set forth in claim 41 wherein said step of establishing includes performing a forward kinematic computation.

52. A method as set forth in claim 51 wherein said calculating step includes calculating both the position and the orientation of the input device.

53. A method as set forth in claim 52 wherein said step of determining includes performing an inverse kinematic computation.

54. A method of controlling a surgical instrument remotely from an input device and by way of an electronic controller, said method comprising the steps of:

inserting the surgical instrument through an incision in the patient so as to dispose the distal end of the instrument at an initial start position;

establishing a fixed position reference coordinate system corresponding to a fixed known position on the surgical instrument at the initial start position of said surgical instrument;

positioning the input device at an initial start position;

establishing a fixed position reference coordinate system representative of the initial start position of said input device;

calculating the current absolute position of the input device as it is controlled;

determining the desired position of the surgical instrument based upon the current absolute position of the input device, and the fixed position reference coordinate system for the respective surgical instrument and input device; and

moving the surgical instrument to the desired position so that the position of the surgical instrument corresponds to that of the input device.

55. A method as set forth in claim 54 wherein said step of positioning the input device includes initializing the location of the input device under control of the controller.

56. A method as set forth in claim 55 wherein said surgical instrument is initially positioned without control from said controller.

57. A method as set forth in claim 54 wherein the initial start position is determined only by manual insertion.

58. A method as set forth in claim 57 wherein the step of positioning the input device comprises initially moving the input device under controller control so as to establish the reference coordinate position of the input device.

59. A method as set forth in claim 58 including storing in the controller the reference coordinate position of the input device.

60. A method as set forth in claim 54 wherein said step of calculating includes performing a forward kinematic computation.

61. A method as set forth in claim 60 wherein said calculating step includes calculating both the position and the orientation of the input device.

62. A method as set forth in claim 61 wherein said step of determining includes performing an inverse kinematic computation.

63. A method of controlling a medical implement remotely from an input device and by way of an electronic controller, said method comprising the steps of:

inserting the medical implement through an incision in a patient so as to dispose the medical implement in a pre-selected initial configuration;

assigning a fixed initial reference coordinate to a work element of the medical implement based upon a known dimension between said work element and a base of the medical implement;

positioning the input device at an initial start position;

establishing a fixed initial reference coordinate representative of the initial start position of the input device;

calculating the current position of the input device as it is controlled;

determining the desired position of the medical implement based upon at least the current position of the input device; and

moving the medical implement so that the position thereof corresponds to that of the input device.

64. A method as set forth in claim 63 wherein said step of inserting the medical implement includes inserting a surgical instrument.

65. A method as set forth in claim 63 wherein said step of inserting the medical implement includes inserting a catheter.

66. A method as set forth in claim 63 wherein said step of inserting the medical implement includes inserting a distal end of the medical implement through the incision so as to be disposed at a target site.

67. A method as set forth in claim 63 wherein said step of inserting the medical implement includes placing the medical implement without pre-computation of a coordinate position at which it is placed.

68. A method as set forth in claim 63 wherein said step of assigning includes placing the medical implement without pre-computation to determine a coordinate position

69. A method as set forth in claim 63 wherein said step of establishing a fixed initial reference coordinate for the input device includes executing a forward kinematic computation to determine the reference coordinate.

70. A method as set forth in claim 69 wherein said step of executing a forward kinematic computation includes determining both the position and orientation of the input device.

71. A method as set forth in claim 69 wherein said step of executing a forward kinematic computation includes determining a position by a geometric calculation.

72. A method as set forth in claim 71 including determining an orientation by a transformation matrix.

73. A method as set forth in claim 63 wherein said step of determining includes performing an inverse kinematic computation.

74. A method as set forth in claim 73 including determining joint angles and insertion length of the instrument.

75. A method as set forth in claim 74 including determining the instrument orientation.

76. A method as set forth in claim 63 wherein said step of determining includes a coordinate transform.

77. A processor and a memory device containing a program of instructions for the processor which include;

receiving an insertion length of a medical instrument inserted in a patient; and

determining a distal end location of the instrument at a target site in the patient from the insertion length.

78. The processor and device of claim 77 wherein the instrument has a straight proximal portion and curved distal portion.

79. The processor and device of claim 78 wherein the instrument lies in a single plane.

80. The processor and device of claim 79 wherein the instrument is a rigid guide member.

81. The processor and device of claim 77 wherein the instrument is inserted and then fixed at a pivot axis outside the patient.

82. The processor and device of claim 81 wherein the pivot axis is generally aligned with an insertion point at which the instrument is inserted into the patient.

83. The processor and device of claim 82 wherein the program of instructions includes determining a subsequent location of the distal end associated with pivoting about the pivot axis.

84. The processor and device of claim 82 wherein the program of instructions includes determining a subsequent location of the distal end associated with axial rotation of the instrument.

85. The processor and device of claim 82 wherein the program of instructions includes determining a subsequent location of the distal end associated with linear translation along a length axis of the instrument.

86. The processor and device of claim 81 wherein the program of instructions includes determining a subsequent movement of the distal end in a single plane about the pivot axis.

87. The processor and device of claim 81 wherein the pivotal axis is a reference point used by the program of instructions in determining subsequent movement of the distal end.

88. The processor and device of claim 77 wherein the program of instructions determines subsequent movement of the distal end in a robotic system.

89. The processor and device of claim 88 wherein a master station controls movement of the distal end at a slave station.

90. The processor and device of claim 88 wherein the processor is disposed between a user input and a drive unit for driving the instrument.

91. The processor and device of claim 77 wherein the program of instructions determines a position and orientation of the instrument.

92. The processor and device of claim 77 wherein the instrument is a guide member.

93. A processor and a memory device containing a program of instructions for the processor which include;

receiving a coordinate representative of the desired location of the distal end of a medical instrument at a target site in a patient; and

determining from said coordinate an insertion length for the medical instrument so as to locate the distal end at the target site.

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